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Evaluation of Best Management Practices at Army Motor Pools To Control Small Spills

by

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Army policies and Department of Defense (DOD) pollution-prevention procedures require cleanup of spills of any size or volume. Army vehicle maintenance shops typically use drip pans and absorbing materials, mostly clay-based compounds, to clean up spills. The use of absorbents (sorbents) to clean spills is the preferred alternative by DOD and Army installations. The U.S. Army Construction Engineering Research Laboratory (CERL) conducted this study to evaluate and summarize the properties of the many commercially available absorbing materials.

This study concludes that no single solution exists to control oil drips and clean up small oil spills at Army motor pools. Most installations

require a combination of drip pans, sorption pads, and sorbing loose material. The study further found that:

1. While election of sorbents is specific to installation and application, in general, cellulose products are the best choice, followed by synthetic products.
2. Disposal of the saturated sorbents is a critical factor in selecting sorbents. Regulatory requirements and cost are key elements in deciding disposal procedures.
3. Training is required for all Army staff on characteristics of different products and their applications to avoid wrong applications that may result in environmental problems.

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Foreword

This study was conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162720A896, "Environmental Quality Technology"; Work Unit TF8, "Stormwater/Wastewater Technology." The technical monitor was Robert Fenlason, CECPW-ES.

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Dr. Michael J. O'Connor is Director of CERL.

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1 Introduction

Background

Army motor pools and military equipment support installations use large volumes of lubricants (oil and grease), hydraulic fluids, and coolants. Engines, transmissions, and hydraulic systems frequently drip these fluids. Oil, grease, and coolants are also spilled in small amounts during routine maintenance operations. Since maintenance is generally performed inside service shops, most of the spills can be cleaned effectively without exposing the materials to rain and runoff. However, drips and leaks from vehicles parked outside result in a large number of small puddles of fluids. The volume of these individual spills is generally small, but their combined effect could result in discharges of pollutants to the environment in concentrations higher than allowed by local, State, and Federal regulations.

Army policies and Department of Defense (DOD) pollution-prevention procedures require cleanup of spills of any size or volume. Indoors, at vehicle maintenance shops, drip pans and absorbing materials (mostly clay-based compounds) are used to clean up spills. Outside, where vehicles are generally parked on paved and unpaved areas, drip pans are used to collect fluids where leaks are observed. In instances where spills and/or significant leaks occur outdoors on the pavement or bare soil, cleanup is done following standard procedures described in spill-control plans. In general, soil contaminated by spills is removed for proper disposal. Large spills on paved areas are cleaned using sorbents similar to materials used for leaks and drips.

The use of absorbents (sorbents) to clean spills is the preferred alternative by DOD and Army installations. A large number of sorbent products are available through GSA schedules and in the open market. At most Army installations, motor pools use clay-based products, usually supplied through GSA contracts. Drip pans made of plastic and metal are used indoors and outdoors to control drips and leaks. Commercial brand containers and pans adapted from metal cans are used by military staff to collect fluids from drips.

The U.S. Army Construction Engineering Research Laboratory (CERL) provides Army installations guidelines for stormwater pollution prevention. Drips and small spills are the principal source of oil and grease in stormwater runoff from Army Motor Pools. CERL is working to identify best management practices (BMPs) to minimize the potential for pollution of runoff from Motor Pools and other Army maintenance facilities. A survey of materials that can be used to control drips and small spills was needed. This report summarizes the findings.

Objective

The purpose of this study was to evaluate and summarize the properties of commercially available absorbing materials for the control and cleanup of drips and spills at Army installations. The investigation evaluated commercially available products. The composition, absorption capacity, physical characteristics, and prices of a variety of the most commonly used products was determined from vendors and manufacturers.

Approach

1. A literature review was undertaken to identify manufacturers and vendors of oil sorbent products.
2. The companies involved were contacted, and required information was collected from the manufacturers' literature, such as Material Safety Data Sheets (MSDSs), composition, packaging, price, and other pertinent data.
3. Samples of sorbent products were collected, evaluated in the laboratory and field situations.
4. Collected information was summarized and conclusions and recommendations were drawn.

Mode of Technology Transfer

This information will be distributed to individual installations, and will be made available through the World Wide Web (WWW) at CERL's URL:

www.cecer.army.mil/publications/techreport

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm ²
1 sq ft	=	0.093 m ²
1 sq yd	=	0.836 m ²
1 cu in.	=	16.39 cm ³
1 cu ft	=	0.028 m ³
1 cu yd	=	0.764 m ³
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 kip	=	453 kg
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32

2 Literature Review

Environment Canada (the Canadian counterpart to the U.S. Environmental Protection Agency [USEPA]) has conducted several studies to evaluate commercially produced oil sorbents. The most recent study (Environment Canada 1991) included evaluations of 16 sorbents and their capabilities to absorb oils and solvents (diesel, crude oil, Bunker C, cyclohexane, and toluene). The sorbents were evaluated to determine their initial and maximum capacities to absorb oil and water, and their reuse potential. The study concluded that organic and synthetic sorbents are the most effective products. Graboil was shown to be the most effective of the synthetic sorbents for solvents and diesel, and yielded average results for heavier oils. Graboil also exhibited the highest water-absorption capacity. Eco Oil sorbent (polyethylene particulates) showed the highest capacity for crude oil (16.98 g/g), while Absorb II (polypropylene) had the greatest capacity for Bunker C (22.15 g/g). Matasorb (polypropylene) also exhibited a high oil-absorption capacity (9.16 g/g). Among organic products, wool was the highest (19.8 g/g) followed by Oclansorb (6.76 g/g), and sawdust (6.65 g/g). Environment Canada also tested the strength of the synthetic sorbents (mat form) after immersion, discovering that Matasorb was the most resistant. Most of the pads weakened after immersion in diesel oil. Many of the sorbents tested had not become saturated even after 48 hours of exposure to heavy oils.

Brinkman (1995) summarizes the concepts of sorption and definitions of absorption versus adsorption, and the impact on selection of the proper material for spills of specific fluids. The key point of his paper is that becoming well versed on the materials and technologies available is essential to environmental compliance and safety.

Schulze (1993) also defined the concepts of absorption and adsorption, as well as the types of sorbents. His paper, as part of the "World Catalog of Oil Spill Response Products" prepared by Environment Canada, provides a general criteria for selection of sorbents, including knowledge about oil/water absorption characteristics (oleophilic/hydrophobic), composition of sorbent (organic, inorganic, or synthetic), biodegradability, disposal limitations, leachability after saturation, reactivity to hydrocarbons, ignitability, and toxicity. The paper also

provides a detailed listing of companies that manufacture or supply different types of sorbents.

The *Compliance Advocate*, a bimonthly newsletter published by Compliance Technologies, summarized some of the properties of commercially available sorbents (Compliance Advocate, Nov/Dec 1992). The editor of this newsletter strongly recommends the use of synthetic sorbents as the best alternative for cleanup of oil spills.

The use of imbibitor beads to control and clean up spills was described in several articles, including Brinkman (1993), who has published several papers promoting this technology. Imbibitor beads are polymer plastics that absorb spilled materials by contact into its molecular structure, swelling in size up to 27 times its initial volume while retaining its structure. Pads filled with beads are suggested as a solution for control of oil spills of organic fluids on water bodies. The author claims that the beads are effective in sealing conduits on contact with fuels and other solvents. Detailed data are not presented to describe the time or concentration necessary to seal pipes of varied diameters.

In 1988, *Pollution Engineering Magazine* published a guide for evaluating absorbent materials. The article analyzes the use (and shortcomings) of loose clay and of other inorganic materials, and concludes that these are the least effective materials.

Most manufacturers and distributors provide sorbent performance information with their products, although such information is frequently not fully supported by laboratory testing or any other type of certification. Additional information on most of the vendors can be found in the References section at the end of this report (p 41).

3 Methods and Procedures

The following procedures were used to collect samples and develop data and information to evaluate absorbing materials:

1. A list of manufacturers and vendors and products was obtained from commercial industrial catalogs and other references.
2. Each manufacturer and/or vendor was contacted by telephone or fax. Table 1 lists the companies/vendors. Each contact was notified that a study of materials that could be used to control and/or clean spills at Army facilities was being conducted.

Samples and information on each type of absorbing material manufactured/sold by the contact was solicited. Information solicited included MSDS, chemical/physical composition, other commercial specifications, packaging, form, price, and any other pertinent data. Samples received were logged and sorted according to the type of materials (pads, pillows, loose material, other).

A sample of each of the materials was tested to determine if the vendor's claims met the general performance characteristics. Testing was conducted at the Fort Campbell Oil Testing Laboratory. For each of the samples, the following tests were performed:

1. *Specific weight for pads or bulk density for loose materials.* A small sample of each material was weighed using an Ohaus analytical balance. Samples were placed in a labeled preweighed beaker, and the gross and net weights obtained (Table 2).
2. *Water absorption capacity.* A known amount of the material was placed in a preweighed beaker containing a known amount of water. The sorbent sample was allowed to soak in the water during a 24-hour period. The sample was then removed and allowed to drain by gravity, after which it was weighed again. The amount of water absorbed was determined from the change in volume in the beaker and verified by the weights of the dry and wet material.

Table 1. Summary of commercial sorbents and principal features (as of 31 December 1995).

Material	Company	Composition or Material	Absorption Ratio gal/lb	Bio-Degradable	Incinerable Btu Value Btu/Lb	Cost / lb or Unit	Remarks
Absorbent GP Pads	Absorption Corp.	Wood pulp	0.9	Yes	16,000		Absorbs all liquids
Absorbent W Pads	Absorption Corp.	Wood pulp	0.9	Yes	16,000		Absorbs mostly oil
Econozorb Pads	Matarah Industries	Polypropylene					Larger fibers than Matasorb, same product
Fiberperl	Sorbent Products	Cellulose/Perlite		Yes			Absorbs mostly oil
H-100 Hydroc. Encap.	JRM Chemical Inc.	Polymer	1.8	No	Yes		Rapid absorption; hydrophobic
Imbiber Beads	Imtech, inc.	Polymer	3.9	No	No		Absorbs organic liquids only
K-Sorb LM	Ecosorb Intern.	Cellulose material	1.4	Yes	8,484	\$0.12	Hydrophobic and hydrophilic brands sold
Lite-Dri	Pig Corporation	Cellulose material	0.4	Yes	7,000	\$0.32	
Matasorb Pads	Matarah Industries	Polypropylene					Oleophylic and hydrophobic
Oclansorb LM	Hi Point Ind. Inc.	Peat and soil	1.7	Yes	7,276		Absorbs mostly oil
Oil-Only Sponge	Breg International	Spagnum moss	2.2				
Oil Sponge	PHase III, Inc.	Cotton, ag. prod.	0.4	Yes	7,000	\$0.66	Absorbs mostly oil
Oil Snare	Price-Darnall Inc.	Plastic fibers	2.9	No	No		For heavy oils; hydrophobic
Oil-Dri Absorbent	Oil Dri Corp. of America	Montmorillonite		No	No	\$0.12	Clay-based material; commonly used at Motor Pools
Pig Mat Hydrophobic	Pig Corporation	Cellulose/polypro.	1.3			\$2.15	
Pig Mat 411-412 Fluids	Pig Corporation	Cellulose/polypro.	1.4			\$3.00	
Pillow-In-A-Pan	Pig Corporation	Cellulose/polypro.	1.1			\$1.60	Small pillow
PSI Light Oil Sorbent	Price-Darnall Inc.	Polypropylene	—	No	—		For light oils; hydrophobic
Sorvasolv	Omni Technology	Cellulose	1.5	Yes	Yes	\$3.00	
SPC Blanket	Sorbent Products	Polypropylene					
SPC Plus Oil Sorbent	Sorbent Products	Polypropylene	2.0		22,000		Oleophylic and hydrophobic
SPC Pads/Rugs	Sorbent Products	Polypropylene	0.5				
SPC SXT	Sorbent Products	Polypropylene	0.5		22,000	\$4.83	
SPC UXT 519	Sorbent Products	Polypropylene					Oleophylic and hydrophilic
Sphag Sorb	Loyola Ent. Inc.	Peat Moss		Yes	9,000	\$0.88	Absorbs mostly oil
Spilftr Cellulose Pad	JV Manuf. Inc.	Cellulose					
Spilftr for Hydrocarbons	JV Manuf. Inc.	Polypropylene		No	Yes		Oil selective; insoluble
Spill Dri	Absorption Corp.	Wood pulp	0.5	Yes	Yes		
Spilstoper/Spildike	Clark Products	Polyurethane		No		\$8.21	Hydrophobic; reusable blocker pad
Supper Sopper Sorbent	Conwed Fiber	Polypropylene	—	No	—	\$2.00	Oleophylic and hydrophobic
Ultrisorb	Molton Co., Memphis	Diatomaceous earth		Yes	—	\$0.23	Particulate material; used at Army Motor Pools
WYK Oil Pads	Upright Inc.	Polypropylene	0.2	No	Yes		Absorbs mostly oil

Material	Company	Composition or Material	Absorption Ratio gal/lb	Bio-Degradable	Incinerable Btu Value Btu/Lb	Cost / lb or Unit	Remarks
Wesorb Oil-Klean Pad	Wesorb Corp.	Wood fibers	4.0	Yes	Yes		Repels water
3M Petroleum Sorbent	3M Corporation	Polypropylene		No	Yes		Hydrophobic
3M T-Series Sorbent	3M Corporation	Polypropylene		No	Yes		
Notes:							
1. Absorption ratios as claimed by manufacturers.							
2. Cost data based on information provided by manufacturers standardized for a weight value.							
3. Oil-water absorption characteristics as reported by manufacturers.							

3. *Oil absorption capacity.* A known amount of material was placed inside a plastic drip pan, after which oil was added until saturation occurred. Point of saturation was established visually when the pad or sample would allow oil to pass into the pan. Oil was added in small known amounts to allow determination of closest volume of saturation.
4. *Oil-water mixture absorption capacity.* A mixture of equal volumes of used engine oil and tap water were mixed in a separation funnel and added in small known amounts to pads or samples of loose sorbents. The mixture was added until saturation was achieved. Water rejected by materials that absorb only oil (hydrophobic materials) was determined by measuring the volume in a graduated cylinder previously weighed.
5. *Absorption capacity of loose materials used to clean a spill of crankcase oil.* This test was done at the 326th Engineer Battalion Motor Pool at Fort Campbell. The test was designed to let soldiers try different types of loose materials to clean small crankcase-oil spills, and was conducted as follows:
 - a. Ten aliquots, 50 ml each, of used crankcase oil were poured on the floor of one of the bays used to repair vehicles at the indicated motor pool. Three sets of aliquots were poured indoors in different areas of the maintenance shop.
 - b. Soldiers assigned to the unit were provided materials to clean the spills, including using the dry-sweep material commonly used at the facility. The samples were not identified as to brand or composition.
 - c. Soldiers were asked to rank the performance of the materials in terms of ease, speed, and efficiency.
 - d. The soldiers' evaluation of each material was recorded on a form for comparison and further analyses.

Table 2. Density of selected sorbents tested during December 1995.

Products	Pad Size sq in.	Pad Wt (Oz)	Unit Wt oz/sq in.	Unit Wt gm/sq cm	Wt Of 4 sq in. pad gm	Loose Material Volume, mL	Dry Beaker Wt (oz)	Bkr + Material Wt (oz)	Loose Material Wt (oz)	Loose Material Wt (gm)	Bulk Density gm/Cm ³
Absorbent W						150.0	5.00	5.40	0.40	11.3	0.08
Absorption Pad I (PIG)	330.0	3.07	0.009	0.041	1.064						
Fiberperl						250.0	4.35	4.80	0.45	12.8	0.05
Lite-Dri						200.0	4.35	5.65	1.30	36.8	0.18
Matasorb	82.0	0.60	0.007	0.032	0.836						
Meltblown Pad	36.0	0.35	0.010	0.043	1.111						
Oclansorb LM						200.0	13.80	14.70	0.90	25.5	0.13
Oil Sponge						300.0	4.40	6.15	1.75	49.6	0.17
Solid-A-Sorb						250.0	4.50	7.90	3.40	96.3	0.39
SPC Blanket	186.0	1.75	0.009	0.042	1.075						
SPC Oil Sorbent	323.0	2.90	0.009	0.040	1.026						
SPC Rugs	230.0	1.10	0.005	0.021	0.547						
SPC SXT	323.0	2.25	0.007	0.031	0.796						
SPC UXT 519	263.3	1.50	0.006	0.025	0.651						
Spilftr Cellulose Pad	36.0	0.30	0.008	0.037	0.952						
Spilftr Fluids	4.0	0.10	0.025	0.111	2.857						
Spilftr Oil	4.0	0.10	0.025	0.111	2.857						
Spill Dri	330.0	3.07	0.009	0.041	1.065	135.0	4.35	5.25	0.90	25.5	0.19
Spill-sorb						130.0	3.60	4.05	0.45	12.8	0.10
Wesorb Pad	240.0	1.25	0.005	0.023	0.595						

4 Use of Sorbents at Army Installations

The use of absorbents (sorbents) to clean spills is the preferred alternative by all Army installations. A large number of products are available through GSA schedules and in the open market. At most Army installations, motor pools use clay-based products, usually supplied through GSA contracts. Drip pans made of plastic and metal are used indoors and outdoors to control drips and leaks. Commercial brands and pans adapted from metal cans are used by military staff to collect fluids from drips.

With adequate care and supervision, drip pans can control most drips. However, the use of drip pans has several disadvantages, including:

1. Daily or more frequent inspections are required to ascertain the pans do not overflow from either rainwater or oil.
2. Removal of the oil from the pans is laborious, and in large motor pools can require significant efforts.
3. Many pans are smashed by vehicles when personnel drive away and forget that the pans are in place. Replacement costs are significant at installations where large number of pans are used.
4. During winter, oil-water mixtures freeze, making it almost impossible to remove the floating oil from the frozen emulsified oil-water mixture.

Drip pans also can be used in combination with "pillows" filled with different types of sorbents. The sorbents in the pillows can absorb most types of fluids, including water, oil, coolant, acids, and other liquids. Removal of the saturated pillows is easier than emptying fluids from the pans. Freezing and overflow is more controlled. The main disadvantage of the pillows is the significantly higher cost when compared to pads or loose material. Pans containing pillows are still exposed to accidental damage by vehicles. Disposal of the saturated pillows can also represent significant costs.

Pans also can be lined with pieces of absorbing pads or even loose absorbing material, which can be removed periodically. Pads are significantly less expensive than pillows and can absorb most fluids. Loose material is even less expensive, although removal from the pan is more laborious. The variety of materials used for pads and loose materials in conjunction with pans can provide flexibility for recovery of several types of fluids and water. Disadvantages of the use of pans previously discussed remain even when these are lined with pads or loose material.

5 Description and Characteristics of Sorbents

Sorbents are materials that have the capability of absorbing both aqueous or oily fluids. They are generally composed of inorganic, natural organic, or synthetic (polymeric) fibers. Sorbents are effective when they provide a large surface area where fluids can adhere, thus promoting *adsorbency*. Adsorbency is then commonly referred as *absorbency*. Fluids adsorb to the inner and outer surface of the sorbents. Air must be present within the inner structure of the absorbent to promote high rates of adsorbency. Maximum absorbency occurs when there is a balance between air space and the maximum surface area within the structure of the materials.

The best sorbents are those composed of fine fibers with large surface areas, but with fibers still large enough to allow adequate air space between each lump of fibers. If there is too much air space between the fibers, the fluid will drain out from the sorbent easily. Optimum absorbency occurs when the fibers are fine and evenly spaced. Materials with these characteristics absorb fluids quickly, in large amounts, and with high retention.

Sorbents can be categorized as hydrophilic (which absorb water), or hydrophobic (which repel it). Some materials are designed specifically to repel water while absorbing petroleum-based products such as oil. Both characteristics are important in the management of spills, and every shop where oil products are used should probably be stocked with both kinds of sorbents.

A relatively large number of products in both categories are marketed with a diversity of additional characteristics. This requires a careful analysis before a particular material is selected for a specific application. Among the characteristics that must be defined are:

1. *Safety*. Chemical compatibility with the fluid is essential to ascertain that reactions producing toxic materials do not occur. Silica and quartz can react with strong acids releasing large amounts of heat. Some materials made of cellulose also can react aggressively with strong acids such as sulfuric acid. Safety also includes inertness and noncorrosivity. Materials should meet

safety standards allowing easy handling without special equipment or tools. Exposure of staff to corrosive or hazardous materials is not allowed under OSHA and other Federal and State regulations.

2. *Changes in Properties.* The sorbent should not change the properties of the fluid. Such reactions could produce toxic materials requiring special handling and disposal.
3. *Chemical and Physical Stability.* While in storage, some sorbents can react chemically with water vapor, changing their physical or chemical composition.
4. *Efficiency.* The ability of the material to absorb fluids is usually expressed as a value related to a unit weight of the sorbents. Typical units are gallons of fluid per unit of sorbent; gallons of fluid per pound of sorbent; and pounds of sorbent required to remove 1 gal of fluid. Absorption also is expressed as a weight ratio, such as "5," meaning that the material can absorb a weight of fluid 5 times the weight of the solvent. This also may be expressed as an efficiency of 500 percent.
5. *Cost.* The cost of sorbents varies significantly. Materials are marketed and priced in a variety of shapes and forms. Pads, socks, loose particles, pillows, rolls, and pellets are among the most common shapes. Unit prices reflect this variety of shapes. The true cost of the materials should be calculated on the basis of the amount of sorbents required for a specific volume of fluid. Also, the disposal cost should be included in the analyses, since some materials are not readily accepted in landfills and require special handling. Generally, sorbents contaminated with oil and lubricants can be landfilled or incinerated. In some States, all materials contaminated with used oil are classified as hazardous wastes, and the disposal cost can be significant. Table 3 summarizes the current regulatory requirements for disposal of used oil and/or materials contaminated with used oil. The data shows that most States do not regulate used oil as a hazardous waste. A growing number of States and even local communities are promulgating and enforcing special regulations to handle disposal of used oil/materials. Only five States consider used oil a hazardous material, requiring special handling, treatment, and/or disposal.

Table 3. Summary of regulatory approach on used oil by individual States.

State	Regulated as HW	Regulated as Special Waste	Not Regulated As HW	Remarks
AL			X	
AK			X	
AZ			X	
AR			X	
CA	X			
CO			X	
CN			X	
DE			X	
DC			X	
FL			X	
GA			X	
HI			X	
ID			X	
IL		X		
IN			X	
IA			X	
KS			X	
KY			X	
LA			X	
ME		X		
MD			X	
MA	X			Revisions to program ongoing.
MI			X	Revisions to program ongoing.
MN			X	
MS			X	
MO			X	
MT			X	
NE			X	
NV			X	
NH	X			
NJ	X			
NM			X	
NY			X	
NC			X	
ND			X	
OH			X	
OK			X	

State	Regulated as HW	Regulated as Special Waste	Not Regulated As HW	Remarks
OR			X	
PA		X		
RI	X			
SC			X	
SD			X	
TN			X	
TX		X		
UT			X	
VT		X		
VA			X	
WA			X	
WV			X	
WI			X	
WY		X		
PR			X	
VI			X	
Notes: Data as of December 1995, modified from USEPA and Thompson Publishing, Inc.				

A key consideration in the selection of sorbents is their biodegradability combined with the final disposal procedure. Federal and State regulations limit the disposal in landfills of free or containerized materials used as sorbents that may biodegrade and release liquids to the site (40 CFR 260, pages 54452-54461). Only materials that meet the "Paint Filter Test" requirements (USEPA 1993) can be disposed of at sanitary landfills in proper containers. Disposal of materials in landfills can represent a significant cost in addition to the environmental impact it represents. The disposal cost of a 55-gal drum of nonhazardous materials at a sanitary landfill ranges from \$400 to \$1,000; the variance is relative to the distance to the landfill and unique requirements of some facilities.

Sorbents that biodegrade are more suitable for incineration, bioremediation, or recycling after the absorbed liquids are released by pressing or squeezing. Heat values of sorbents saturated with oil can be as high as 16,000 BTU, resulting in a net energy gain. Incineration may be restricted or limited by local, State, or Federal air pollution regulations and restrictions. Bioremediation has been practiced at several installations (Fort Bragg, Fort Riley), and can be a more economical and environmentally sound solution than landfilling and incineration. Many reputable companies provide bioremediation of soils and materials contaminated with oil products at prices ranging from \$30 to \$200 per ton of material. Recycling of sorbents after oil products are pressed out appears

to be feasible, but in reality is a labor- or capital-intensive activity with limited benefits. Collection, transport, handling, pressing, re-collection, and re-distribution of recycled sorbents requires sizable people resources. Absorption of oil products into the matrix of a sorbent, although a physical process, results into strong bonds that retain large amounts of the oil-based products.

Types of Sorbents

A large number of sorbents are composed of organic, inorganic, and synthetic materials (Table 1):

1. *Organic Sorbents.* These include straw, peat, saw dust, and wood products, including chips and re-processed cellulose, ground corn cobs, poultry feathers, wool products, cork, charcoal, clay, and other similar products.
2. *Inorganic Sorbents.* These substances include minerals such as perlite, vermiculite, glass wool, and soft volcanic rocks. Matrices within these compounds adsorb and absorb fluids.
3. *Synthetic Sorbents.* These products include polymeric materials such as polyurethane, polyethylene, polypropylene, nylon fibers, and urea formaldehyde foam.

Sample commercial products in each of these categories include:

1. *Clay Minerals.* Inorganic clay minerals have a bulk density of about 32 lb per cubic feet (lb/cu ft). These compounds are heavy and hard, usually milled into small chips. Typical absorbencies are less than 300 percent.
2. *Vermiculite.* This is also a mineral composed mostly of clay and hydrated silicate minerals related to the chlorites. After mining, vermiculite is expanded to allow more air into its fiber structure, resulting in a density of about 8 lb/cu ft. The absorbency efficiency of vermiculite ranges from 400 to 600 percent. The light weight of vermiculite makes it impractical for use in loose form, but it can be very effective in packages such as socks or pillows.
3. *Cellulose-based Materials.* Originated from plant and pulp materials, these products are usually manufactured from pulp residues, recycled paper, ground corn cobs, and sawdust. Typically, cellulose products biodegrade and can be incinerated. Unless chemically treated, they are hydrophilic, i.e., they

also absorb large volumes of water. These materials have efficiencies ranging from 200 to 500 percent. Products based on cellulose should not be used with aggressive materials such as acids, since chemical reactions will occur that may result in toxic compounds.

4. *Polymeric or Synthetic Materials.* These synthetic compounds are specifically designed for absorption of fluids, with efficiencies as high as 1,000 percent. Typical compounds include polypropylene and polyethylene, which are highly resistive to chemical degradation. These products offer superior chemical resistance to absorb acids or other aggressive fluids.

Most synthetic materials are hydrophobic, although they can be treated with detergents or surfactants to promote water absorption. Care also should be exercised when applying these materials where coolants or other liquids with detergents are present, since a hydrophobic material can then become hydrophilic.

Physical and Chemical Properties of Sorbents

Samples of sorbents provided by vendors were tested to determine their bulk weight and ability to absorb oil and water. Tests were performed as described in the methods and procedures section of this report. Testing was limited by the following factors:

1. Vendors were not prompt in providing samples to conduct the tests. The timeframe limitations to complete the project and report forced initiation of the tests with an incomplete set of samples from all the vendors contacted. Some vendors, in spite of several calls, never sent any samples.
2. Some of the vendors that were late in supplying the samples provided physical and performance data about their products. The data was incorporated into the summary presented in Table 1.
3. Data about one of the most important tests on sorbents (the "Paint Filter Test" to determine capacity for saturated sorbents to leach fluids) was not provided by many vendors. This test is discussed in another section of this report.

Efficiency of Materials To Absorb Lubricants

The efficiency of materials in absorbing fluids is generally reported in terms of the ratio of weight of fluid absorbed per unit weight of sorbent material. These claims of absorbency generally apply to pads and loose material. Partial laboratory tests of 22 products supplied by vendors are discussed in the following sections and summarized in individual tables.

Most vendors provide data and information claiming absorption capabilities for the products they offer. There are no standard tests to determine the capacity for a sorbent to capture fluids, particularly lubricants. Oils and other liquid lubricants vary in their density, which increases as the lubricants are used in internal combustion engines or hydraulic systems. A standard test would be difficult to define since there is a myriad of products with different properties that react differently to changes in temperature and pressure. In the field, during a spill, a product is desired that quickly will absorb a maximum volume or weight of lubricant, retaining it once the material is recovered.

Absorption of lubricants by the products evaluated was tested under simulated field conditions. Samples of materials and products were exposed to used lubricants (engine, aviation, and hydraulic oils) obtained from the Oil Testing Laboratory at Fort Campbell. Lubricants were added to a known amount of the sorbent until saturation. The point of saturation was determined visually when oil began to seep from the material into an underlying watch glass. The results of the oil absorption tests are summarized in the following sections.

Absorption of Engine Oil

Used engine oil from military vehicles and aircraft throughout Fort Campbell was obtained from the Oil Testing laboratory. Samples of the absorption products were then placed in preweighed beakers and oil was added until saturation was evident. For products sold as pads, a sample with an area of 4 sq in. was used; its bulk density was previously determined by weighing the full pad. A known volume of products marketed as loose particles (particulate material, LM) was weighed to determine their mass. The amount of oil absorbed was determined by weighing the saturated sample. The results of the tests (Table 4) show that:

1. The cellulose and propylene products show the highest absorption ratios among the materials tested. Absorption efficiencies for used oil ranged from

0.15 to 25.3 g of oil/gram sorbent. Pads manufactured of wood fibers and cellulose have the highest absorption ratios for used oil; peat moss and sphagnum moss products have the lowest absorption ratios.

2. The weight of the amount of oil absorbed was determined from dual calculations using the differences in weight before and after saturation, and separately from the volume of oil added to the pad (using its specific weight). Comparison of the calculations by the two methods (saturation method as index) ranged from 80 to 104 percent, averaging 96 percent, indicating the results were reliable.
3. Visual observations indicated that the wood-based products absorb oil much faster than the synthetic fibers. Leachate tests were not conducted, but it is logical to assume that release of the oil also would be faster from cellulose-based products.

Table 4. Absorption of engine oil (used) by selected sorbents.

Material	Dry Bkr Wt (Oz)	Bkr +Mat Dry (gm)	Weight Sorbent (gm)	Oil Added (mL)	Oil Wt (gm)	Oil Sorbed/gm (Gm/Gm)	Bkr + Pad Wt (oz)	Bkr Pad Wt (gm)	Recovery Saturation %
Absorbent TM	3.75	106.28	10.90	20.00	19.00	1.74	4.50	127.53	92.97
Absorbent W	3.75	106.28	11.30	20.00	19.00	1.68	4.40	124.70	90.64
Absorption Pad I	3.75	106.28	1.06	3.50	3.33	3.14	3.85	109.11	98.44
Absorption Pad II	3.75	106.28	1.10	10.00	9.50	8.64	4.00	113.36	96.58
Fiberperl	3.75	106.28	12.80	15.00	14.25	1.11	4.25	120.45	89.83
Lite-Dri	3.75	106.28	36.80	20.00	19.00	0.52	4.65	131.78	80.81
Matasorb	3.60	102.02	0.84	8.50	8.08	9.61	3.85	109.11	97.98
Meltblown Pad	3.60	102.02	1.11	12.00	11.40	10.27	3.95	111.94	97.23
Oclansorb LM	3.75	106.28	25.50	20.00	19.00	0.75	4.65	131.78	86.83
Oil Sponge	3.75	106.28	25.50	20.00	19.00	0.75	4.55	128.95	84.96
Solid-A-Sorb	3.75	106.28	96.30	15.00	14.25	0.15	4.60	130.36	59.92
SPC Blanket	3.60	102.02	1.08	16.50	15.68	14.51	4.10	116.19	97.15
SPC Oil Sorbent	3.60	102.02	1.03	8.00	7.60	7.38	3.85	109.11	98.25
SPC Rugs	3.60	102.02	0.55	4.00	3.80	6.91	3.70	104.86	98.39
SPC SXT	3.60	102.02	0.80	5.00	4.75	5.94	3.80	107.69	99.88
SPC UTX 519	3.60	102.02	0.65	4.50	4.28	6.58	3.75	106.28	99.16
Spilltr Cellulose Pad	3.60	102.02	0.95	10.00	9.50	10.00	3.90	110.53	97.83
Spilltr Fluids	3.75	106.28	2.86	20.00	19.00	6.64	4.35	123.28	95.47
Spilltr Oil	3.75	106.28	2.86	21.00	19.95	6.98	4.75	134.62	103.44
Spill Dri	3.75	106.28	1.06	10.00	9.50	8.96	4.30	121.86	103.86
Spill-sorb	3.80	107.69	12.80	20.00	19.00	1.48	4.60	130.36	92.79
Wesorb Pad	3.60	102.02	0.60	16.00	15.20	25.33	4.05	114.78	96.76

The second set of tests was made with an oil-water mixture. The mixture was created by combining oil and water, in equal proportions, and then by agitating the mixture in a separation funnel for about 1 minute, after which it was added to the sorbents. Saturation was determined from visual observations when either water or oil was released from the material, depending whether hydrophobic or hydrophilic products were being tested. The results of the saturation tests of the sorbents with the oil-water emulsion (Table 5) show that:

1. The absorption ratios ranged from 0.43 to 18.5 g/g. The cellulose (wood products) compounds absorbed the largest amount of the emulsion. Spill-Dri (wood pulp) and Absorbent GP pads showed the highest absorption ratios. SPC Blankets also reflected high absorption ratios of the emulsion.
2. The weight of the amount of oil-water mixture absorbed was determined from dual calculations using the differences in weight before and after saturation, and separately from the volume of oil-water mixture added to the pad (using its specific weight). Comparison of the calculations by the two methods (saturation method as index) ranged from 61 to 102 percent, averaging 94 percent, indicating the results were reliable. The "Solid-A-Sorb" sample reflected a recovery of only 60.8 percent, likely an error in the weighing step.

Table 5. Absorption of engine oil-water mixture by selected sorbents.

Material	Dry Bkr Weight (Ounces)	Bkr + Mat Dry (Grams)	Weight Sorbent (Grams)	Oil-Water Added (Ml)	Oil-Water Weight (Grams)	Grams Oil Sorbed/Gm (Gm/Gm)	Bkr + Pad Weight (Ounces)	Bkr + Pad Weight (Grams)	Water Recovered (Grams)	Recovery Of Water Percent
Absorbent TM	3.75	106.28	10.90	20.00	19.60	1.80	4.45	126.11	0.00	91.94
Absorbent W	3.50	99.19	11.30	30.00	29.40	0.83	4.10	116.19	20.00	96.94
Absorption Pad I	3.55	100.61	1.06	10.00	9.80	9.25	3.80	107.69	0.00	96.44
Absorption Pad II	3.6	102.02	1.10	18.00	17.64	16.04	3.90	110.53	0.00	91.25
Fiberperl	3.75	106.28	12.80	38.00	37.24	2.52	4.75	134.62	5.00	88.88
Lite-Dri	3.55	100.61	36.80	40.00	39.20	0.93	4.70	133.20	5.00	77.90
Matasorb	3.55	100.61	0.84	10.00	9.80	11.67	3.80	107.69	0.00	96.63
Meltblown Pad	3.60	102.02	1.11	10.00	9.80	8.83	3.90	110.53	0.00	97.69
Oclansorb LM	3.75	106.28	25.50	40.00	39.20	0.16	4.50	127.53	35.00	94.62
Oil Sponge	3.45	97.77	25.50	40.00	39.20	0.56	4.30	121.86	25.00	89.95
Solid-A-Sorb	3.75	106.28	96.30	42.00	41.16	0.43	5.25	148.79	0.00	60.83
SPC Blanket	3.60	102.02	1.08	15.00	14.70	13.61	3.80	107.69	0.00	91.18
SPC Oil Sorbent	3.60	102.02	1.03	10.00	9.80	9.51	3.85	109.11	0.00	96.51
SPC Rugs	3.60	102.02	0.55	5.00	4.90	8.91	3.70	104.86	0.00	97.48
SPC SXT	3.60	102.02	0.80	7.00	6.86	8.58	3.70	104.86	0.00	95.48
SPC UTX 519	3.60	102.02	0.65	5.00	4.90	7.54	3.80	107.69	0.00	100.02
Spilfr Cellulose Pad	3.60	102.02	0.95	6.00	5.88	6.19	3.90	110.53	0.00	101.42
Spilfr Fluids	3.75	106.28	2.86	30.00	29.40	6.78	4.50	127.53	10.00	98.85
Spilfr Oil	3.75	106.28	2.86	32.00	31.36	7.47	4.55	128.95	10.00	98.45
Spill Dri	3.60	102.02	1.06	20.00	19.60	13.77	4.20	119.03	5.00	100.77
Spill-sorb	3.45	97.77	12.80	20.00	19.60	0.75	4.35	123.28	10.00	102.07
Wesorb Pad	3.60	102.02	0.60	10.00	9.80	16.33	3.95	111.94	0.00	99.40

Absorption of Aviation Oil

Army installations with air-assault or other airborne units use large volumes of aviation lubricants for fixed and rotary-wing aircraft. Samples of used aviation lubricants were provided by the Oil Testing Laboratory at Fort Campbell. Tests performed on the samples were similar to those conducted for the used engine oil. The results of the tests (Table 6) show that:

1. Absorption rates of aviation oil by sorbents were slightly lower than for engine oil, ranging from 0.14 to 15.0 grams/gram.
2. Samples from sorbents manufactured from cellulose (wood products), e.g., Wesorb and Absorption Pad II showed the highest absorption rates. Polypropylene pads marketed as Matasorb also show high absorption capacity.

Table 6. Absorption of aviation oil (used) by selected sorbents.

Material	Dry Bkr Wt (oz)	Bkr + Mat Dry (gm)	Weight Sorbent (gm)	Oil Added (mL)	Oil Weight (gm)	Gm Oil Sorbed/Gm (Gm/Gm)	Bkr + Pad Wt (oz)	Bkr + Pad Wt (gm)	Recovery Saturation %
Absorbent TM	3.75	106.28	10.90	20.00	18.00	1.65	4.55	128.95	94.00
Absorbent W	3.75	106.28	11.30	19.00	17.10	1.51	4.50	127.53	93.38
Absorption Pad I	3.75	106.28	1.06	3.00	2.70	2.55	3.90	110.53	100.17
Absorption Pad II	3.75	106.28	1.10	17.00	15.30	13.91	4.30	121.86	97.98
Fiberperl	3.55	100.61	12.80	16.00	14.40	1.13	4.20	119.03	91.98
Lite-Dri	3.60	102.02	36.80	15.00	13.50	0.37	4.35	123.28	80.14
Matasorb	3.60	102.02	0.84	10.00	9.00	10.71	3.95	111.94	99.18
Meltblown Pad	3.55	100.61	1.11	13.00	11.70	10.54	4.00	113.36	98.82
Oclansorb LM	4.35	123.28	25.50	47.00	42.30	1.66	6.15	174.29	89.02
Oil Sponge	3.75	106.28	25.50	20.00	18.00	0.71	4.60	130.36	85.89
Solid-A-Sorb	3.55	100.61	96.30	15.00	13.50	0.14	4.70	133.20	62.86
SPC Blanket	3.55	100.61	1.08	7.00	6.30	5.83	3.80	107.69	99.08
SPC Oil Sorbent	3.60	102.02	1.03	10.00	9.00	8.74	3.95	111.94	99.02
SPC Rugs	3.60	102.02	0.55	4.50	4.05	7.36	3.75	106.28	99.25
SPC SXT	3.55	100.61	0.80	5.00	4.50	5.63	3.80	107.69	101.21
SPC UTX 519	3.55	100.61	0.65	5.50	4.95	7.62	3.80	107.69	100.88
Spilfr Cellulose Pad	3.60	102.02	0.95	15.00	13.50	14.21	4.10	116.19	98.49
Spilfr Fluids	3.60	102.02	2.86	19.00	17.10	5.98	4.25	120.45	97.22
Spilfr Oil	3.75	106.28	2.86	19.00	17.10	5.98	4.45	126.11	98.42
Spill Dri	3.75	106.28	1.06	16.00	14.40	13.58	4.45	126.11	102.25
Spill-sorb	3.75	106.28	12.80	13.00	11.70	0.91	4.55	128.95	97.63
Wesorb Pad	3.60	102.02	0.60	10.00	9.00	15.00	3.95	111.94	99.40

3. The weight of the amount of oil absorbed was determined from dual calculations using the differences in weight before and after saturation, and separately from the volume of oil added to the pad (using its specific weight). Comparison of the calculations by the two methods (saturation method as index) ranged from 63 to 102 percent, averaging 97 percent, indicating that the tests were reliable.
4. Tests of absorption with a mixture of aviation oil and water resulted in similar results, with values ranging from 0.25 to 22.7 grams/gram (Table 7). Products manufactured from cellulose and wood products reflect the higher absorption ratios. The highest ratios were observed in samples from Spilltr Cellulose Pad and Wesorb. High absorption ratios also were observed in polypropylene products such as Matasorb.

Table 7. Absorption of aviation oil-water mixture by selected sorbents.

Material	Dry Bkr Wt (Ounces)	Bkr + Mat Dry (gm)	Wt Sorbent (gm)	Oil-Water Added (MI)	Oil-Water Wt (gm)	gm Oil Sorbed/Gm (Gm/Gm)	Bkr + Pad Wt (Ounces)	Bkr + Pad Wt (gm)	Water Recovered (gm)	Recovery Of Water %
Absorbent TM	3.45	97.77	10.90	40.00	38.00	2.57	4.50	127.53	10.00	92.51
Absorbent W	3.75	106.28	11.30	33.00	31.35	1.00	4.35	123.28	20.00	95.15
Absorption Pad I	3.45	97.77	1.06	5.00	4.75	4.48	3.60	102.02	0.00	98.26
Absorption Pad II	3.45	97.77	1.10	15.00	14.25	8.41	3.75	106.28	5.00	97.72
Fiberperl	3.45	97.77	12.80	19.00	18.05	0.24	3.85	109.11	15.00	95.78
Lite-Dri	3.75	106.28	36.80	45.00	42.75	1.16	5.20	147.37	0.00	78.36
Matasorb	3.55	100.61	0.84	9.00	8.55	6.61	3.75	106.28	3.00	98.94
Meltblown Pad	3.55	100.61	1.11	10.00	9.50	8.56	3.80	107.69	0.00	96.40
Oclansorb LM	4.35	123.28	25.50	46.00	43.70	1.71	4.50	127.53	0.00	65.47
Oil Sponge	3.45	97.77	25.50	20.00	19.00	0.55	4.20	119.03	5.00	86.57
Solid-A-Sorb	3.60	102.02	96.30	25.00	23.75	0.25	4.90	138.87	0.00	62.18
SPC Blanket	3.60	102.02	1.08	15.00	14.25	13.19	3.80	107.69	0.00	91.18
SPC Oil Sorbent	3.55	100.61	1.03	10.00	9.50	9.22	3.75	106.28	0.00	95.20
SPC Rugs	3.55	100.61	0.55	5.00	4.75	8.64	3.75	106.28	0.00	100.11
SPC SXT	3.55	100.61	0.80	5.00	4.75	5.94	3.80	107.69	0.00	101.21
SPC UTX 519	3.55	100.61	0.65	5.00	4.75	7.31	3.80	107.69	0.00	101.35
Spilltr Cellulose Pad	3.60	102.02	0.95	28.00	26.60	22.74	4.30	121.86	5.00	96.86
Spilltr Fluids	3.60	102.02	2.86	32.00	30.40	8.88	4.45	126.11	5.00	95.78
Spilltr Oil	3.55	100.61	2.86	8.00	7.60	(0.84)	3.90	110.53	10.00	108.13
Spill Dri	3.45	97.77	1.06	23.00	21.85	(2.97)	4.45	126.11	25.00	124.03
Spill-sorb	3.80	107.69	12.80	20.00	19.00	0.70	4.50	127.53	10.00	97.89
Wesorb Pad	3.60	102.02	0.60	10.00	9.50	15.83	3.90	110.53	0.00	98.14

Absorption of Transmission Oil

Absorption tests of used transmission oil were conducted at the Fort Campbell Oil Testing Laboratory. Tests performed were similar than for the engine and aviation oil samples, including a mixture of oil-water. The results of the tests for the used transmission oil show:

1. Absorption ratios ranged from 0.15 (Solid-A-Sorb Clay Product) to 21.7 grams/gram (Wesorb). Similar to the tests for engine and aviation oil, the highest absorption ratios were observed in products manufactured from cellulose (wood products), followed by synthetic fibers made of polypropylene (Table 8).
2. Tests with a transmission oil-water mixture show that the highest ratios are observed in products made of wood pulp that have affinity for water (Table 9). Absorption ratios for the oil-water mixture ranged from 0.34 (clay-based products) to 26.6 (Spill-Dri).

Table 8. Absorption of transmission oil (used) by selected sorbents.

Material	Dry Bkr Wt (Ounces)	Bkr +Mat Dry (gm)	Wt Sorbent (gm)	Oil Added (MI)	Oil Wt (gm)	gm Oil Sorbed/Gm (Gm/Gm)	Bkr + Pad Wt (Ounces)	Bkr + Pad Wt (gm)	Recovery Saturation %
Absorbent TM	3.45	97.77	10.90	20.00	18.60	1.71	4.15	117.61	91.40
Absorbent W	3.45	97.77	11.30	20.00	18.60	1.65	4.15	117.61	91.12
Absorption Pad I	3.45	97.77	1.06	3.50	3.26	3.07	3.60	102.02	99.70
Absorption Pad II	3.45	97.77	1.10	10.00	9.30	8.45	3.75	106.28	97.61
Fiberperl	3.75	106.28	12.80	15.00	13.95	1.09	4.25	120.45	89.83
Lite-Dri	3.75	106.28	36.80	11.00	10.23	0.28	4.25	120.45	78.17
Matasorb	3.60	102.02	0.84	7.50	6.98	8.30	3.80	107.69	97.58
Meltblown Pad	3.55	100.61	1.11	10.00	9.30	8.38	3.85	109.11	97.67
Oclansorb LM	3.75	106.28	25.50	10.00	9.30	0.36	4.15	117.61	82.96
Oil Sponge	3.45	97.77	25.50	20.00	18.60	0.73	4.35	123.28	86.04
Solid-A-Sorb	3.75	106.28	96.30	16.00	14.88	0.15	4.65	131.78	60.29
SPC Blanket	3.60	102.02	1.08	10.00	9.30	8.61	3.90	110.53	97.72
SPC Oil Sorbent	3.55	100.61	1.03	8.00	7.44	7.22	3.85	109.11	99.52
SPC Rugs	3.55	100.61	0.55	4.00	3.72	6.76	3.70	104.86	99.72
SPC SXT	3.55	100.61	0.80	6.00	5.58	6.98	3.80	107.69	100.27
SPC UTX 519	3.60	102.02	0.65	4.00	3.72	5.72	3.75	106.28	99.63
Spilltr Cellulose Pad	3.55	100.61	0.95	10.00	9.30	9.79	3.85	109.11	97.81
Spilltr Fluids	3.75	106.28	2.86	15.00	13.95	4.88	4.25	120.45	97.03
Spilltr Oil	3.75	106.28	2.86	10.00	9.30	3.25	4.10	116.19	97.53
Spill Dri	3.45	97.77	1.06	17.00	15.81	14.92	4.20	119.03	102.76
Spill-sorb	3.80	107.69	12.80	10.00	9.30	0.73	4.35	123.28	94.47
Wesorb Pad	3.60	102.02	0.60	14.00	13.02	21.70	4.05	114.78	98.42

Absorption of Water

Sorbents are marketed as hydrophilic or hydrophobic; most manufacturers offer both types of products to recover different types of fluids. Oleophilic pads and loose materials are engineered to recover oil from water or from other surfaces, repelling water. This is an excellent feature for spills of oil products on water bodies and hard surfaces. In contrast, products are also available that recover both oil and other fluids, including water. These products are more suitable for recovery of oil from soils. It is important that, in the selection of a particular product for a specific spill-control application, the water-absorbing capacity be known. Use of a product that absorbs water to remove oil from a pond or creek could result in the material sinking, thus compounding the clean-up process.

Although most manufactures claim that hydrophobic products are completely impermeable, in practice all the products absorb some water. Determinations were made of the water absorption capacity of the products evaluated during the project. Laboratory experiments were conducted by submerging weighed samples of each product in a known volume of water. The samples were allowed to soak in the water for a period of 24 hours. The materials were removed from the containers, drained, and re-weighed to determine the amount of water absorbed. The results were validated by weighing the residual water separately.

The water-absorption test results are summarized in Table 10, which show:

1. Water absorption ratios ranged from 0.95 to 7.84.
2. The highest water-absorption ratios were observed in products manufactured from wood pulp and cellulose marketed for general fluids. Treatment of these products with chemical dispersants can reduce the capacity to absorb water.
3. Most of the products marketed as hydrophobic (repelling water) show absorption ratios close to 1.0, essentially repelling water.
4. Most of the products made of synthetic materials are formulated to repel water, and exhibit water-absorption ratios close to 1.0.

Table 9. Absorption of transmission oil-water mixture by selected sorbents.

Material	DRY BKR Wt (oz)	BKR +MAT Dry (gm)	Wt Sorbent (gm)	Oil-Water Added (mL)	Oil Wt (gm)	gm OIL Sorbed/Gm (gm/gm)	Bkr + Pad Wt (oz)	Bkr + Pad Wt (gm)	Water Recovered (gm)	Recovery of Water %
Absorbent TM	3.45	97.77	10.90	45.00	42.75	2.55	4.75	134.62	15.00	97.36
Absorbent W	3.45	97.77	11.30	38.00	36.10	2.75	4.55	128.95	5.00	91.08
Absorption Pad I	3.45	97.77	1.06	4.00	3.80	3.58	3.65	103.44	0.00	100.59
Absorption Pad II	3.45	97.77	1.10	20.00	19.00	17.27	3.90	110.53	0.00	92.98
Fiberperl	3.45	97.77	12.80	40.00	38.00	1.02	4.35	123.28	25.00	98.48
Lite-Dri	3.45	97.77	36.80	35.00	33.25	0.77	4.55	128.95	5.00	78.99
Matasorb	3.55	100.61	0.84	10.00	9.50	11.31	3.80	107.69	0.00	96.63
Meltblown Pad	3.55	100.61	1.11	10.00	9.50	8.56	3.80	107.69	0.00	96.40
Oclansorb LM	3.45	97.77	25.50	47.00	44.65	1.75	4.85	137.45	0.00	80.72
Oil Sponge	3.45	97.77	25.50	27.00	25.65	0.86	4.45	126.11	3.75	86.42
Solid-A-Sorb	3.45	97.77	96.30	40.00	38.00	0.34	4.85	137.45	5.00	60.86
SPC Blanket	3.60	102.02	1.08	15.00	14.25	13.19	3.85	109.11	0.00	92.38
SPC Oil Sorbent	3.60	102.02	1.03	37.00	35.15	4.03	3.75	106.28	31.00	98.02
SPC Rugs	3.60	102.02	0.55	5.00	4.75	8.64	3.70	104.86	0.00	97.48
SPC SXT	3.55	100.61	0.80	5.00	4.75	5.94	3.70	104.86	0.00	98.54
SPC UTX 519	3.55	100.61	0.65	5.00	4.75	7.31	3.70	104.86	0.00	98.68
Spilltr Cellulose Pad	3.55	100.61	0.95	11.00	10.45	11.00	4.10	116.19	0.00	103.23
Spilltr Fluids	3.45	97.77	2.86	40.00	38.00	9.79	4.55	128.95	10.00	98.80
Spilltr Oil	3.45	97.77	2.86	20.00	19.00	4.90	4.35	123.28	5.00	106.34
Spill Dri	3.45	97.77	1.06	35.00	33.25	26.65	4.70	133.2	5.00	103.26
Spill-sorb	3.75	106.28	12.80	20.00	19.00	0.70	4.50	127.53	10.00	98.89
Wesorb Pad	3.60	102.02	0.60	11.00	10.45	17.42	3.95	111.94	0.00	98.52

Table 10. Absorption of water by selected commercial sorbents.

Products	Dry Bkr Wt (oz)	Bkr + Pad Wt (oz)	Bkr + Pad Wt (gm)	Net Wt Pad/Mat (Ounces)	Net Wt Pad/Material (gm)	mL Water Added	Saturated Pad+Hoh (gm)	Residual Hoh Plus Beaker (gm)	Residual Water (gm)	Water Absorption Ratio (G/G)	Reaction Upon Addition Of Water
Absorbent TM	3.75	4.55	128.95	0.80	22.67	300.0	428.95	174.29	68.02	4.41	Absorbs water readily
Absorbent W	3.75	4.50	127.53	0.75	21.25	300.0	427.53	145.95	39.68	7.56	Absorbs water readily
Absorption Pad I	3.75	3.90	110.53	0.15	4.25	300.0	410.53	192.71	86.44	3.47	Absorbs water readily
Absorption Pad II	3.75	4.30	121.86	0.55	15.59	300.0	421.86	195.55	89.27	3.36	Absorbs water readily
Fiberperl	4.35	4.80	136.03	0.45	12.75	138.0	274.03	167.21	43.93	3.14	Loose material; saturates
Lite-Dri (PIG)	4.35	5.65	160.12	1.30	36.84	205.0	365.12	296.15	172.87	1.19	Loose material; saturates
Matasorb	6.25	6.35	179.96	0.10	2.83	300.0	479.96	480.36	303.24	0.99	Repels water
Meltblown Pad	3.55	4.00	113.36	0.45	12.75	300.0	413.36	-	-	-	Material spilled, test aborted
Oceansorb LM	4.35	6.15	174.29	1.80	51.01	300.0	474.29	123.28	0.01	-	Absorbed all the water
Oil Sponge	4.40	4.45	126.11	0.05	1.42	300.0	426.11	196.96	72.27	4.15	Absorbs water readily
Solid-A-Sorb	4.50	7.90	223.89	3.40	96.35	300.0	523.89	417.79	290.26	1.03	Saturated rapidly; sinks
SPC Blanket	3.75	4.05	114.78	0.30	8.50	300.0	414.78	415.18	308.91	0.97	Repels water
SPC Oil Sorbent	5.00	5.20	147.37	0.20	5.67	300.0	447.37	442.10	300.40	1.00	Not absorption initially
SPC Rugs	5.20	5.35	151.62	0.15	4.25	300.0	451.62	406.68	259.31	1.16	Absorbs water readily
SPC SXT	4.95	5.15	145.95	0.20	5.67	300.0	445.95	426.52	266.23	1.05	Floats; repels water
SPC UTX 519	5.00	5.10	144.53	0.10	2.83	300.0	444.53	403.85	262.15	1.14	Absorbed water readily
Spilltr Cellulose Pad	3.70	3.80	107.69	0.10	2.83	300.0	407.69	284.82	179.96	1.67	Saturated rapidly; sinks
Spilltr Pad for Hydrocarbons	3.75	3.85	109.11	0.10	2.83	300.0	409.11	233.81	127.53	2.35	Absorbed water readily
Spilltr Oil (blue) Loose Mat.	3.55	3.80	107.69	0.25	7.08	102.0	209.69	208.30	107.69	0.95	Repels water
Spill Dri	3.75	4.45	126.11	0.70	19.84	300.0	426.11	175.71	69.43	4.32	Absorbed water readily
Spill-sorb	3.75	4.55	128.95	0.80	22.67	300.0	428.95	144.53	38.26	7.84	Absorbed water readily
Wesorb Pad	4.90	5.15	145.95	0.25	7.08	310.0	455.95	-	-	-	Repels water; test aborted

6 Field Tests of Sorbent Products

Limited field tests were conducted of the absorption characteristics of selected commercial sorbent products. The tests were limited by the following factors:

1. Availability of samples of materials. Vendors did not forward samples as quickly as needed to meet the project timetable.
2. Scope of the project to evaluate alternatives to drip pans.
3. Availability of data from vendors and other sources.

The scope of the tests included:

1. Spilling a small amount of oil (engine, aviation, and transmission) on the floor of a typical Army Motor Pool.
2. Providing staff in the Motor Pool (military) samples of the materials available to clean and/or control the spill.
3. Observing the cleanup procedure and recording observations and comments made by the Army staff.

Currently, at most Army Motor Pools, clay-based dry-sweep is used to clean most small spills. At Fort Campbell, Oclansorb also is used, as well as pads provided by PIG Corporation. Similar uses were documented at other Army installations. The prevailing product in the typical motor pool is the dry-sweep clay compound obtained from GSA sources.

The field tests of sorbents were conducted at the 887th Engineer Company, 326th Engineering Battalion. The unit provides maintenance to light and heavy vehicles inside the shop. SP4 Hartley Combee, from the indicated unit, performed the tests. Two separate tests were conducted:

1. Absorption of used oil from the floor of the shop using 13 of the products available.
2. SP4 Combee then selected the two products that, in his opinion, performed best (efficiency to absorb the spilled oil and speed). These were retested to compare their performance
3. The two best materials and the Solid-A-Sorb clay-based product available in the Motor Pools were tested on a mixture of oil and water. Absorption was observed and recorded.
4. The time during which the absorbents were left soaking the materials was limited to 15 minutes; longer soaking times may result in different performance for different products.

The results of the tests in the Motor Pool are summarized in Table 11, and show that:

1. Cleanup of spills of oils on the floor of the Motor Pool was easier with cellulose based products. The best results were obtained with Fiberpel, Oil Sponge, and Oclansorb.
2. Although the dry-sweep (Solid-A-Sorb and similar products) are effective in cleaning spills from the concrete surface, they require mixing to enhance absorption. Soldiers are "trained" to use their boots to step on the material covering the spill to speed and enhance the process. This practice results in some oil adhering to the sole of the boots, which later spreads over other areas.
3. Cellulose-based absorbents with smaller particles are more effective than those with larger particles.
4. The second test of the two products that appear to perform best (Fiberpel and Oil Sponge) showed that:
 - a. Fiberpel would be best for lighter oils (aviation, transmission) than for heavier used oils.
 - b. Oil Sponge performed better in absorbing heavier oils, although some mixing was required.

5. The third test included spilling a mixture of oils and water, and placing the three absorbents (Fiberpel, Oil Sponge, and Solid-A-Sorb) on the spill. The results show that:
 - a. Oil Sponge performed best among the three products. This matches the water-absorption tests previously discussed, where Oil Sponge readily absorbs water.
 - b. Fiberpel performed slightly less efficiently, since the product absorbs less water than Oil Sponge, although it removed the oil equally effectively.
 - c. The dry-sweep material was less effective, and required mixing to remove the spills.

Table 11. Summary of field tests of particulate absorbents at Fort Campbell, KY-TN during November 1995.

<i>Test 1: Absorption of used engine oil from shop floor. Observations from SP4 Combee.</i>	
<i>Volume of oil spilled - 50 ml, covered with particulate material and left in place 15 minutes.</i>	
Material	Observations
Absorbent W	Fair to poor. Large particles, does not get saturated.
Fiberperl	Good, fast. Absorbed all oil.
Lite-Dri	Very large particles, minimal absorption.
Oclansorb LM	Absorbs well after mixing against spill; does not get saturated in time limit.
Oil Sponge	Absorbs well, but requires mixing for complete absorption.
Solid-A-Sorb	Poor absorption independently; requires mixing and still leaves a wet area.
Spilftr Oil	Did not absorb all the oil; poor results.
Spill Dri	Absorbs well, but requires mixing for complete absorption.
Spill-sorb	Did not absorb all the oil; poor results.
<i>Test 2: Absorption of used engine, aviation and transmission oil from shop floor.</i>	
<i>Volume of oil spilled - 50 ml, covered with particulate material and left in place 15 minutes.</i>	
Material	Observations
Fiberperl	Good, fast absorption of aviation and transmission oil; requires mixing for crankcase oil.
Oil Sponge	Excellent for crankcase oil, minimum time and mixing. Good for aviation and transmission oil.
<i>Test 3: Absorption of water-oil mixtures of engine, transmission, and aviation oil from shop floor.</i>	
<i>Volume of oil-water mix spilled - 50 ml of each mixture covered with sorbent and left in place 15 minutes.</i>	
Material	Observations
Fiberperl	Second best for all three types of oil.
Oil Sponge	Excellent absorption, quick with no effort. Best performance.
Solid-A-Sorb	Least effective on all three oils. Leaves pool of oil and is slow.

7 Benefits and Disadvantages of Materials Tested

The results of the data collection and laboratory field tests provide general guidance that can be used to select the most effective sorbents for a particular application. The following key factors should be considered in future sorbent acquisition and application programs at Army installations:

1. *Efficiency to absorb oil.* Different materials show significant variations in absorbing efficiency, in terms of volume and weight absorption capacity. Claims of absorbing efficiency made by vendors need to be verified against a common standard. The Army needs to define the best possible standard to measure absorbency, and to require that all vendors provide data from an independent laboratory.
2. *Ability to absorb or repel water.* The nature and location of a spill of oil can dictate the sorbent that will be most effective. Use of a sorbent that soaks water in a pond or stream could result in a serious environmental problem that would require a costly cleanup if the material sinks. Military staff are not normally informed of the characteristics of these materials, and could use the wrong sorbent accidentally. Most of the commercial products absorb water, albeit some marketed as hydrophobic absorb only small amounts. Test data should be required from all vendors from an independent laboratory showing water absorption ratios.
3. *Disposal of used sorbents.* Sorbents saturated with oil products can be incinerated, landfilled, re-used, or treated biologically.
 - a. Incineration can be an effective energy-producing activity where allowed by regulations. Environmental sensitivity to incineration needs to be considered. Capital investments of incinerators require detailed cost/benefit analyses to determine the feasibility of incineration.
 - b. Landfilling of saturated sorbents is the preferred alternative practiced by the Army. Disposal by landfilling, albeit efficient, may represent long-term environmental problems if biodegradable sorbents in containers are

punctured or crushed, releasing oils to the landfill. Sorbents used by the Army should be exposed to the Paint Filter Test, and products that do not meet this criteria should not be procured. The cost of landfilling should be compared to incineration and bioremediation to ascertain the most economical, but environmentally sensitive, disposal process.

- c. Biotreatment of saturated sorbents can be an effective and cost-savings measure, but is feasible only if the products biodegrade. Careful selection of sorbents that meet bioremediation criteria is needed. Claims of suitability of commercial sorbents for bioremediation need to be verified by independent testing, and included in manufacturers data.
4. *Acquisition Cost.* Cost data for the products surveyed and tested were limited and difficult to analyze. Manufacturers produce sorbents in a large number of forms, shapes, and composition. Unit values (per pound) are not easily identified for most products. Each installation needs to perform cost analyses to determine the most cost-effective products for their specific applications. Cost data should include:
 - a. *Acquisition Cost.* Most of the products surveyed were not on GSA schedules, negating the savings the Army might realize with large procurements. Vendors complained about the difficulties (paper work) to list their products on GSA schedules.
 - b. *Disposal Cost.* Disposal costs vary with type of disposal (landfilling, incineration, bioremediation), location, and organization used for the disposal. A detailed cost analysis to optimize these costs is needed at each installation to minimize expenditures.
 - c. *Storage and Handling.* The Army typically does not factor storage and handling costs in the selection of sorbents. Cost of warehouse space, utilities, and staff to handle the materials from procurement to use, all need to be evaluated.
 5. *Reuse Potential.* Actual reuse of sorbents is very limited at Army installations. Reductions in civilian and military staff hinder any significant efforts to reuse sorbents by pressing or squeezing oil into other containers.
 6. *Effectiveness in Different Weather Conditions.* Testing of sorbents as part of this project was limited to the conditions prevailing at Fort Campbell during November. Temperatures ranged from 50 to 55 °F, with clear skies and

humidity at about 30 percent. Extreme cold or hot climatic conditions could result in significant differences in performance by specific sorbents:

- a. Hydrophilic sorbents stored in humid places over long periods can absorb water from the air, reducing their effectiveness.
- b. Extremes of temperature change the viscosity of oils and fuels. The absorption capabilities of different materials decrease with increased viscosity.

Although MSDSs provide some information about stability, additional data should be obtained from tests by independent laboratories. Packaging could be improved to seal most sorbents and limit water absorption while in storage.

7. *Availability on GSA Schedules.* Most of the products surveyed are not available on GSA schedules. An effort is required to maximize the inclusion of the best products on GSA procurement contracts, with potential savings in funds.
8. *Vendor Information.* Vendor information is limited and difficult to obtain. Products are sold by manufactures, second party distributors, and over the counter at warehouses. A data base of the vendors is needed (updated periodically) to determine availability of products. New products are not readily available. The Army or some other Federal organization could develop a project to maintain a data base of sorbents information.

8 Alternatives for Motor Pool Operations

What is the best alternative between pans, pads, loose material, or a combination of these? The best alternative is probably unique to each facility and installation.

1. Indoors, it is probably most effective to use pads, or a combination of pans and pads, for most drips. Larger spills can be cleaned with a combination of pads, loose material, and even booms ("socks"). Loose material is probably more effective to clean up large spills.
2. Outdoors, pads are probably more effective to collect small drips and clean up larger spills. Although loose materials also can be effective outdoors, their recovery requires more effort.
3. The use of drip pans will continue to be an alternative to minimize oil spills from drips. Pans should be placed only on vehicles that drip, and not on every vehicle in the Motor Pool. A program of daily inspections in the motor pool is required to minimize spills from drips. The Storm Water Pollution Prevention Plan (SWP³) and Spill Prevention Control and Countermeasure Plan (SPCCP) provide for these inspections.

9 Summary and Conclusions

A large variety of sorbents are available to control drips and spills of oils and lubricants, as well as other fluids. Inorganic, organic, and synthetic compounds are processed or manufactured in a variety of forms and shapes, including loose material, pads, pillows, rugs, socks, and booms. Clay-based minerals in loose forms, pillows and socks, including vermiculite, are the main inorganic products. Organic sorbents include materials composed of cellulose from recycled or waste wood products, peat, corn cobs, and similar agricultural wastes, packaged as loose materials, pads, rugs, pillows, socks, and booms. Synthetic compounds are generally made of extruded polypropylene fibers, urethane, and polymers.

A large number of commercial sorbent products are available, including inorganic, organic, and synthetic compounds. A general survey resulted in data for 37 products, samples, and detailed information were obtained for 22 materials. The most predominant materials are made of wood products (residues or recycled), polypropylene, and clay-based minerals such as vermiculite. Cellulose and moss are the main components of the organic products.

Oil absorption ratios (by weight) for the sorbents tested ranged from 0.15 to 25 grams oil/gram material. Several of the products, mostly wood fiber products and polypropylene compounds, provide excellent retention of the sorbed oil and are hydrophobic.

Laboratory tests of the materials show that:

1. Cellulose products have the highest absorbencies of used oil, followed closely by polypropylene fibers. Inorganic materials show the least absorbency.
2. Most of the materials tested absorb water, albeit several synthetic and cellulose products absorb only small amounts of water.
3. The efficiency of the materials tested is affected by several factors, including composition, size of fibers, form, and presence of water. Effects of temperature or pressure were not evaluated.

4. Uniform performance data from independent certified laboratories are not available for many of the products. Claims of performance are not fully documented for many products. Some of these claims were contradicted in the limited testing conducted during the project.

Field testing of some of the most commonly used materials showed that:

1. Sorbents manufactured from cellulose and synthetic compounds have the highest sorption ratios, although organic materials sorb a known amount of oil more quickly. Inorganic materials, such as dry sweep commonly used at Army installations, absorb less oil and require more time.
2. Military personnel are not commonly aware of the differences among the three types of materials, and use each material based more on availability than on the materials performance properties. Clay-based products, provided through GSA sources, are commonly used at Army motor pools for all types of oil drips and spills. Drip pans are used as required, but the staff prefers to clean spills from drips over the burden of placing and emptying the pans.
3. Control of oil drips and cleanup of small oil spills at Army motor pools cannot be achieved through a single solution. A combination of drip pans, sorption pads, and sorbing loose material is required for each facility. The Spill Control Contingency Plan (SCCP) and the Stormwater Pollution Prevention Plan, through an operations Standing Operating procedure (SOP), need to be tailored to optimize the use of these control measures. The SOP should include:
 - a. Training of military and civilian staff on the properties of the different types of sorbents. Training should also be provided on the labeling of containers to identify the type of spill on which a sorbent should be used. Training should include a continuous information program to environmental staff and operational personnel.
 - b. Providing sources and materials suitable for different types of spills, to maximize cleanup, while minimizing potential environmental impacts.

The following conclusions and recommendations are derived from the results of the project:

1. Selection of sorbents is unique for each installation and application, but in general, cellulose products are the best choice followed by synthetic products.
2. Disposal of the saturated sorbents should be a critical factor in the selection of sorbents. Regulatory requirements and cost are the key elements in deciding the disposal procedures.
3. Training is required for all Army staff on the specific characteristics of the different products and their particular applications. Lack of knowledge about the use of specific sorbents can easily result in wrong applications and more complex environmental problems.
4. Additional data on products and vendors are required to optimize the procurement efforts. Claims of performance need to be standardized through specifications for testing by independent laboratories. Procurement should be limited to materials providing support performance data.

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